The Federal Role In Weather Modification

Domestic Council
Environmental Resources Committee
Subcommittee on Climate Change

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Subcommittee on Climate Change
Environmental Resources Committee
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EXECUTIVE SUMMARY

Economic losses due to weather extremes and severe weather events have steadily increased. Increasing population and property development make it likely that this will continue. The present and growing water shortages in many areas of the Nation have also created serious problems of National concern.

Weather modification represents a potential tool for exerting a favorable influence over destructive weather events and for augmenting water supplies in some areas where additional water is needed for energy, food, and fiber production.

General Recommendation

- A policy should be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research and in the beneficial application of the technology along the lines of the recommendations embodied in this report.

Specific Findings and Recommendations

A. RESEARCH

Findings

- Present Federal strategy in research in weather modification is to develop techniques to achieve particular objectives such as augmenting water resources or diminishing the damage from hurricanes. The strategy does not view the development of a weather modification science and technology as a specific national goal whose achievement would allow many different applications as needs arise.

- This strategy, which encourages the individual agencies to conduct weather modification research in pursuit of their assigned missions, has divided the research responsibility, while budgetary limitations over the past several years have produced a situation in which many individual projects are marginally staffed, funded, and operated.

- The level of scientific and technological complexity of even modest weather modification experimentation requires a higher level of funding than has usually been available to accomplish individual project goals.

- While progress has been generally slow and uneven, some advancement has been achieved over the past two decades in several types of weather modification research under existing policies.

- More vigorous encouragement and development of the fundamental knowledge of the physics and dynamics of cloud processes are necessary to permit adequate development of the potential of this field.

Recommendations

- The Federal Government should recognize weather modification as having significant potential for ameliorating important weather-related problems and foster a broad-based effort of research and experimentation in weather modification designed to realize this potential during the next decade.

- The Federal Government should examine its institutional structure for planning and management of the national weather modification effort to carry out its responsibilities for research and experimentation. The Subcommittee identified two practical institutional options but could not achieve consensus on either. A decision should be made between the following options:

  Option (1) Continue coordination and planning of the national weather modification effort through the Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology, with individual agencies pursuing their mission responsibilities.

  Option (2) Establish a lead agency to foster the broad advancement of the science and technology of weather modification as recommended by the National Advisory Committee on Oceans and Atmosphere, the National Academy of Sciences, and other groups to coordinate and plan the national effort with the assistance and participation of other agencies.

- Weather modification research in general should be funded at an increased level to ensure that present marginal efforts can be transformed into significantly more productive activities.

- The Federal Government should develop and support a more vigorous program of fundamental research and experimentation in the physics and dynamics of cloud processes to advance weather modification technology and its application.

- Greater emphasis in research should be placed on the assessment of the socioeconomic and environmental impacts of weather modification.

- Greater emphasis should be placed on the development of improved methodologies to evaluate the effects of weather modification.

B. OPERATIONS

Findings

- Few operational weather modification techniques have been thoroughly proven.

- Several weather modification techniques are sufficiently close to a stage of proven effectiveness that they should be considered as management options in some situations.

Recommendations

- When and if weather modification techniques are determined feasible and desirable for a given situation, the Federal Government should reserve for itself the responsibility in the following areas:

  - Precipitation modification related to water resources benefiting several states and to projects under Federal jurisdiction.

  - Weather modification to improve conditions over airports, roads, ports, National Forests, and other lands under Federal jurisdiction.

  - Mitigation of large-scale (more than one State) developing drought, with the concurrence and cooperation of the States involved, where it is determined that the effects may be widespread or threaten the Nation's welfare.

  - Mitigation of hurricanes and other extensive storm systems, which affect more than one State and represent a major threat to life and property.

- The States and private sector should be encouraged to consider operational weather modification as a management option addressed to problems other than those specified above as being Federal responsibilities.

- Private sector capabilities should be used in the conduct of Federal weather modification operations where both feasible and desirable.

C. REGULATION

Findings

- Additional Federal regulatory legislation is not needed at this time.

- Present reporting procedures have fulfilled an important need.

- Given the significant amount of activity in the field as well as the potential for increased use of the technology, prudence dictates a continuing examination of the need for Federal laws and regulations and international treaties and agreements to govern weather modification activities.

Recommendations

- A formal procedure should be established for the periodic reassessment of regulatory needs, based on an ongoing review of operational weather modification activities.

- The design and implementation of future U.S. domestic and foreign weather modification activities should include prior assessment of the potential international implications.

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PREFACE

The Domestic Council's Environmental Resources Committee, at the request of the Council, formed the Subcommittee on Climate Change in August 1974. One element of the Subcommittee's charter was to examine and make recommendations on the Federal role in weather modification research, operations, and regulation.

The Subcommittee is composed of representatives drawn from the Departments of Agriculture, Commerce, Interior, State, and Transportation; the Council on Environmental Quality; the National Aeronautics and Space Administration; the National Science Foundation; and the Office of Management and Budget. The Department of Defense participated as an observer in discussions on weather modification.

In preparing its report, the Subcommittee has drawn substantially from recent documentation on the progress, status, and problems in weather modification and, through a two-day open hearing, from well-informed representatives of the scientific community, commercial sector, state governments, conservation groups, agriculturalists, and the legal field. Although inadvertent changes in the weather that may be caused by human activity are discussed briefly, the Subcommittee limited itself to deliberate weather modification in developing its conclusions and recommendations.

The Subcommittee recognized the increasing level of activity in weather modification in other countries and the role that the United States may play in those programs. Also recognized was the fact that domestic use of weather modification techniques has the potential for international impacts. However, because of time and resource limitations, the Subcommittee decided to limit the scope of this report to domestic concerns.

THE POTENTIAL BENEFITS OF WEATHER MODIFICATION

Most human activity is directly or indirectly influenced by weather. Historically, man has attempted to modify his activities to take advantage of prevailing weather and minimize the effects of adverse weather. During the last quarter century, however, he has been attempting to develop techniques by which he can manage the weather as a resource for his benefit and for the protection of life and property.

Although early interest in weather modification centered on increasing economic benefit through stimulation of local precipitation, there has been an increase in research directed toward reducing losses from adverse weather and certain weather-related disasters. Reduction of losses due to severe storms invites particular attention because losses are often large for any single event and, because of increasing urban development in vulnerable areas, average annual property losses are increasing drastically.

Property damage caused by hurricanes has been increasing in the United States since early in the Twentieth Century while loss of life has been decreasing. Improvements in the hurricane warning service and in community preparedness programs are saving lives. Expansion of cities into vulnerable areas and construction along coasts are largely responsible for the increased annual property loss, now estimated to exceed $780 million (table 1) with large variation from year to year. Relatively few storms cause most of the damage.

Property damage from tornadoes has increased dramatically over the past three decades. Damages during 1970-1974 averaged $360 million per year, approximately 10 times the annual average during 1940-1944. Tornado-related deaths during 1970-1974 averaged 140 per year, approximately

Table 1. Annual property damage and loss of life from weather-related disasters and hazards in the United States and FY 1975 Federal weather modification research funding

Weather Hazard	Loss of Life1/	Property Damage1/ (Billions of Dollars)	Modification Research (Millions of Dollars)
Hurricanes	30 (1970-74 Avg.)	0.8 (1970-74 Avg.)	0.8*
Tornadoes	140 (1970-74 Avg.)	0.4 (1970-74 Avg.)	1.0**
Hail	-	0.8 (1973)	3.9
Lightning	110 (1950-72 Avg.)	0.1	0.4
Fog	1000 (Avg.)	0.5 (Avg.)	1.3
Floods	240 (1965-69 Avg.)	2.3 (1965-69 Avg.)	-
Frost (Agric.)	-	1.1 (Avg.)	-
Drought	-	0.7 (Avg.)	3.4#
Totals	1520	6.7	10.8

* These funds do not include capital investment in research aircraft and instrumentation primarily for hurricane modification, which in FY 1975 amounted to $9.2 million.

** These funds support theoretical research on modification of extratropical cloud systems and their attendant severe storms such as thunderstorms and tornadoes.

\# These funds support precipitation augmentation research, much of which may not have direct application to drought alleviation.

1/ Sources: Assessment of Research on Natural Hazards, Gilbert F. White and J. Eugene Haas, The MIT Press, Cambridge, Mass., 1975, pp 68, 286, 305, 374; The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1976, U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Washington, D.C., April 1975, p 9; Weatherwise, Feb. 1971, 1972, 1973 1974, 1975, American Meteorological Society, Boston, Mass.; Summary Report on Weather Modification, Fiscal Years 1969, 1970, 1971, U.S. Department of Commerce, NOAA, Washington, D.C., May 1973, pp 72, 81; Estimating Crop Losses Due to Hail - Working Data for County Estimates, U.S. Department of Agriculture, Economic Research Service, Sept. 1974; Natural Disasters: Some Empirical and Economic Considerations, G. Thomas Sav, National Bureau of Standards, Washington, D.C., Feb. 1974, p 19; Traffic Safety Magazine, National Safety Council, Feb. 1974.

16 percent less than during 1940-1944, undoubtedly the result of improvements in the timeliness and accuracy of tornado forecasts and public response to the forecasts.

Other severe weather events that cause substantial damage in the United States for which reasonably reliable loss figures are available are hail and lightning. In 1973 the annual hail damage to crops in the United States totaled $680 million. Damage to other property brought the U.S. 1973 hail damage figure to over $750 million. The average annual lightning-caused forest fire damage exceeds $100 million, not including cost impacts of the reduction in esthetic value and possible further damage due to floods from denuded watersheds.

A fifth weather hazard, fog, costs domestic airlines more than $80 million per year due to aircraft delays, diversions, and cancellations. Fog-associated accidents on the Nation's highways and in the Nation's ports cause approximately 1000 deaths and damages in excess of $400 million each year.

The average annual cost in the United States directly identified with selected impacts of these five hazards - hurricanes, tornadoes, hail, lightning, and fog - exceeds two billion dollars. It is more difficult to assign a precise dollar value to losses suffered as a result of other forms of adverse weather, particularly extremes in precipitation and temperature. Conservative estimates, however, place annual average losses from floods and frosts in excess of three billion dollars, with frost being primarily an agricultural problem. Weather is, in fact, the most significant variable explaining year-to-year fluctuations in the yield of most agricultural crops. It has been estimated, for example, that drought

(a period when water is deficient enough for long enough to cause serious crop damage over a sizable area) causes average annual crop losses in excess of $700 million. There are, however, large year-to-year variations in these losses, ranging near zero in optimum growing years to billions of dollars in years with severe drought conditions. For example, loss estimates from crop damage in Nebraska alone as a result of the 1974 drought totaled approximately one billion dollars.

Weather modification is one alternative, albeit technically limited, available to decrease the risk of loss from weather hazards. Other alternatives include relocating economic and population centers to low-risk areas; constructing weather-proof facilities; or expanding hazard insurance coverage. To the extent that weather modification is economically more attractive than its alternatives, it should be employed. However, it is recognized that not all weather-related losses can be prevented. Consider hurricane losses for example. Weather modification has the potential of reducing winds and wind damage, but there are no present techniques which could reduce losses due to heavy rainfall and inland flooding. Therefore, the potential gain in practicing weather modification would not be a full recovery of the $780 million loss as shown in table 1, but only a fraction of the loss attributed to wind damage effects. In a similar sense, weather modification to ameliorate damage from tornadoes, hail, and lightning could only be selectively practiced due to the widespread occurrence of these storms and the difficulty in predicting their occurrence. Nevertheless, even a ten percent reduction of losses from severe storms, drought, and fog would save $300 to $400 million annually. Present Federal investment in weather modification research, however, is

insufficient to make substantial progress toward these levels of return in the near future.

Most existing experimental weather modification techniques are inexpensive to apply compared to their potential utility. Estimated benefit-to-cost ratios of potential weather modification technologies range from about 3 to 1 for fog dissipation at airports, 30 to 1 for precipitation augmentation, and as high as 100 to 1 for hurricane moderation. In a few cases the benefits to some may be partially offset by losses to others, but there may well be sufficiently large net benefits to enable compensation programs in those instances.

For example, it has been estimated that an additional inch of rain in North Dakota during the growing season could provide $100 million in direct benefits through increased crop production plus an additional $200 million in indirect income within the state economy. The cost of a statewide precipitation augmentation program would be less than $2 million per year.2/ While it is not proven that an additional inch of rain can be produced consistently by cloud seeding, a 2700 square mile pilot project in North Dakota has shown that such changes are within the realm of possibility.3/

Such favorable benefit-cost-ratios offer inducements to make use of promising ideas as they are developed. A strong responsibility rests upon the Federal Government to develop, test, evaluate, and refine these techniques and to document ancillary consequences.

2/ The Effects of Added Rainfall During the Growing Season in North Dakota, North Dakota State University, June 30, 1974.

3/ Evaluation by Monte Carlo Tests of Effects of Cloud Seeding on Growing Season Rainfall in North Dakota, by A.S. Dennis, et al., J. Appl. Meteor. V. 14, No. 5, August 1975, p. 959-969.

Social acceptability of both research and operational weather modification has varied considerably with location in the United States and elsewhere. In Florida the fear of additional rain from a cloud seeding experiment harming tomato crops at critical stages of development caused curtailment of the seasonal duration of the program. Potential avalanche danger in the Colorado Rockies and impact on hunters have restricted experiments in snowpack augmentation. There have been attempts to halt operational programs through court injunctions and even through violence. Such problems have not been the rule and good communications and public relations have usually minimized unfavorable reactions. Nevertheless, it is clear that social, environmental, and international concerns must be fully explored to assess the potential adverse impacts of routine application of weather modification techniques.

THE STATE OF THE ART

The principal focus for weather modification concerns and activities are:

1. Fog and stratus cloud dissipation;
2. Precipitation enhancement;
3. Severe storm amelioration, including intensity reduction, redistribution of precipitation, and hail and lightning suppression;
4. Inadvertent weather and climate modification; and
5. Deliberate climate modification.

The ability to achieve a modification objective varies significantly. In some categories progress has been substantial; in others research has only begun. Few modification techniques have been scientifically proven to be completely effective and dependable. Nonetheless, some deliberate weather modification is practiced as a commercial service sold to private groups and local and Federal Government entities. Approximately 65 percent of these services are directed at precipitation enhancement. The remaining operations are divided nearly equally between fog dispersal and hail suppression.

Briefly, the state of the art in weather modification may be summarized as follows:

1. Fog and stratus cloud dissipation

   - Supercooled (water droplets at a temperature below freezing) fog and stratus can be cleared from airports. Operational systems for cold fog dispersal have been established at some U.S. Air Force bases and at some commercial airfields in the United States and in several foreign countries.

- Warm fog (at a temperature above freezing) dissipation has been demonstrated as technically feasible in certain meteorological situations. The only operationally proven technique, however, is the application of heat over airport runways to evaporate fog.

2. Precipitation enhancement

- Snowfall in certain mountainous areas of the western United States can be increased locally by 15 to 20 percent and in some instances redistributed by seeding winter orographic clouds. This capability was established to the satisfaction of much of the scientific community during the 1960's at Climax, Colo., and is being tested in other mountainous regions of the West. Private weather modifiers, however, have been conducting operational winter orographic cloud seeding to increase snowpack for power companies and water interests for over 20 years. These programs have been commercially funded and endorsed; however, they have not been designed for rigorous scientific evaluation.

- Long-term seeding experiments conducted in Southern California, Israel, and Australia to stimulate precipitation from winter convective systems have provided significant positive results. Israel recently converted to an operational seeding program supported by continuing research aimed at improving this technology. Winter convective systems usually consist of convective cells embedded in stratiform cloud decks. There is persuasive evidence of sizeable extra-area effects as a result of seeding

winter convective storms. Apparent increases in rainfall on seeded occasions have been found 80 to 150 miles downwind of seeding sites in southern California.

- Recent experiments in the Plains States, especially those in the Dakotas, and experiments in Florida involving randomized, ice-nuclei seeding of summer convective clouds strongly suggest that precipitation can be enhanced from some isolated cumulus clouds. "Seedable" clouds, as determined by simple computer cloud models, produce more precipitation when seeded than when not seeded. However, the majority of summer rainfall comes not from isolated clouds but from organized convective systems. Results from experiments in organized cloud systems over fixed target areas have not been as conclusive although recent findings of the North Dakota Pilot Project are promising.4/ Four years of seeding research in Florida over a target area of 4900 square miles have shown that the natural variability of convective rainfall is far greater than the additional rainfall expected from seeding, thereby making definitive proof of rain increases elusive. Despite the lack of definitive proof of success, operational application of convective cloud seeding to augment precipitation has been extensive under the sponsorship of state and county governments and primary water users, especially in agricultural regions such as North and South Dakota, Texas, and Oklahoma.

4/ Ibid.

3. Severe storm amelioration

- Hail suppression is a form of precipitation modification for which some success is reported. Most hail suppression operations in the United States are conducted by commercial cloud seeders under contract to state and county governments and community associations. Hail suppression operations are conducted extensively in foreign countries. However, the lack of a satisfactory system for evaluating the results of these operations leaves many important questions unanswered. Three years of field experimentation by the National Hail Research Experiment (NHRE) have not provided sufficient information and understanding to answer these questions.
- Results of field experiments to suppress lightning activity by silver iodide seeding have been ambiguous. Although the analysis is continuing, the seeding program has been terminated. In recent experiments in lightning suppression, thunderstorms were seeded from below with chaff (very fine metalized nylon fibers), and the number of lightning occurrences was observed to be about 25 percent of that observed in the control storms (based on an analysis of data from 10 seeded thunderstorms and 18 unseeded control storms). Although the experiments were not strictly randomized, statistical evaluation indicated that the observed difference between seeded and control storms was significant.
- Hurricane modification research and field experiments suggest that the maximum winds in hurricanes might be reduced by 10

to 15 percent if the appropriate clouds of the storms are seeded with freezing nuclei. Additional experiments are needed, however, to determine if the observed reductions in maximum wind are truly results of the seeding. There is no indication that the hurricane track or associated precipitation can be modified.

- Tornado suppression is beyond the present state of the art with little hope for success in the near future. Long-term investigations have been initiated recently into the modification of cyclonic storm systems and the mitigation of their attendant severe weather.

4. Inadvertent weather and climate modification

- A major field project, the Metropolitan Meteorological Experiment (METROMEX), was established in 1971 at St. Louis, Mo., to study the effects of urbanization on various aspects of atmospheric behavior (inadvertent regional climate modification). Preliminary results show that the St. Louis urban-industrial complex influences summertime convective storm behavior, increasing the average precipitation by 20 to 30 percent and the intensity and frequency of severe weather including hail by even greater amounts in localized areas within 25 miles downwind of the city center.
- Studies are being conducted to assess the large-scale impact of man's activities on climate (inadvertent global climate modification). Thermal pollution, particulate pollution, and increased generation of such gases as CO_2, NO_2 and chlorofluoromethanes are being studied. For example, the Climate

Impact Assessment Program has examined the effect of high altitude aircraft. A global network of monitoring stations is being established to determine baseline values of small, variable trace constituents of the atmosphere and to determine the effect of long-term trends in these trace constituents on global weather and climate. These data will provide input for diagnostic and prognostic numerical global models being developed to predict climate changes resulting from man's activities. At this time, however, knowledge about inadvertent modification processes is insufficient to allow definitive conclusions.

5. Deliberate climate modification

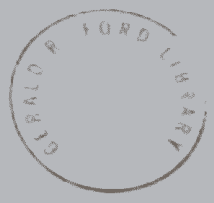
- The United States Government is not giving serious attention to any proposals to intentionally modify climate over sizeable areas.

THE ROLE OF THE FEDERAL GOVERNMENT

The Subcommittee on Climate Change is charged with examining the Federal role in domestic weather modification activities. Deliberation by the Subcommittee included a two-day open hearing at which selected individuals with valid concerns and well-formed views on the Federal role in weather modification were invited to testify. Speakers included representatives from the research community, private operators, the legal sector, state governments, conservation groups, and agriculturalists.

In addressing the Federal role in weather modification, the Subcommittee limited itself to those activities identified earlier as deliberate weather modification. The Subcommittee examined separately issues in research, operational programs, and regulation and concluded that there is a need for a Federal policy covering these areas. It is recommended, therefore, that:

- *A policy be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research and in the beneficial application of the technology.*



Specific findings and recommendations which could form the basis for such a policy are presented in this section of the report.

A. Research

Weather modification encompasses many research areas. Fundamental research is conducted in cloud physics, cloud dynamics, and in natural and artificial nucleation. Equipment development includes measuring instruments and delivery and observing systems. Supporting studies include numerical and physical modeling, analysis and evaluation studies, field

experimentation, and special studies of the sociological, ecological, economical, legal, and international impacts of weather modification. Although field experimentation is the most visible part of the program, it represents only a portion of the total Federal research effort in weather modification.

An identifiable coordinated Federal research program in weather modification has been in existence at least since 1959 when the National Science Foundation, in response to Public Law 85-510, established a program to support studies, research, and evaluation in the field of weather modification. After a slow beginning, Federal funding for deliberate weather modification research increased steadily from $3.7 million in FY 1965 to a peak of $18.7 million in FY 1972. Support for the program decreased 34 percent to $12.4 million in FY 1975. As shown in table 2, six Federal agencies have participated in this research program. FY 1976 planned expenditures indicate an increase of $1.7 million with the support being increasingly concentrated in three agencies, the Departments of Commerce and Interior and the National Science Foundation.

The Subcommittee recognized that the Interdepartmental Committee for Atmospheric Sciences (ICAS) figures, which form the basis for table 2, have excluded capital investments in Department of Commerce aircraft and instrumentation used primarily for weather modification. In FY 1976 these additional funds amounted to $5.5 million.

Table 2 also includes the FY 1976 planned expenditures for research in meteorology, as defined in the ICAS annual reports on the national atmospheric sciences program. These include research and development expenditures in such areas as physical and dynamic meteorology, observation,

description, prediction, and dissemination, and major support items such as highly instrumented research aircraft. Clearly, funding for weather modification research is a small amount embedded in a much larger program of atmospheric research. However, many facets of the larger program relate to weather modification and provide indirect benefits.

Table 2. Agency Funding for Deliberate Weather Modification Research Compared with Total FY 1976 Funding for Meteorological Research[5/] (Millions of Dollars)

Agency	FY 72	FY 73	FY 74	FY 75	FY 76	Total FY 76 Meteorology Funding
Dept. of Agriculture	0.4	0.3	0.3	0.1	0.1	2.3
Dept. of Commerce	3.9	3.8	3.3	2.7	3.3	53.7
Dept. of Defense	1.8	1.2	1.2	1.3	0.5	26.1
Dept. of Interior	6.7	6.4	3.9	3.5	4.6	4.6
Dept. of Transportation	0.4	0.4	0.1	0.1	0.0	11.7
Nat'l Science Foundation	5.5	6.2	4.7	4.7	5.6	45.9
Other Federal Agencies	0.0	0.0	0.0	0.0	0.0	64.3
Totals	18.7	18.3	13.5	12.4	14.1	208.6

Virtually all research in weather modification in this country has been Federally supported. In reviewing the Federal role in this area of research, the Subcommittee noted with concern the lower level of support for conducting research programs during recent years. The Subcommittee unanimously feels that the Federal Government must recognize and fulfill its commitment to research in weather modification. Greater nonfederal participation should be encouraged. States are now contributing in some instances. For example, some state governments have made funds available to participate in the Bureau of Reclamation High Plains Cooperative Program,

5/ National Atmospheric Sciences Program Fiscal Year 1976, Interdepartmental Committee for Atmospheric Sciences, Washington, D.C., ICAS 19-FY76, May 1975.

and one state is participating in METROMEX. It is hoped that such state government involvement in research will continue. There appears to be little incentive for private industry to invest its own resources in research in weather modification.

The magnitude of individual experimental weather modification projects dictates Federal responsibility. In major weather modification projects, such as the hurricane modification experiments, there can be no question concerning the Federal role. Clearly, such projects must remain the responsibility of the Federal Government if for no other reason than the immensity of the undertakings, the social and international implications, and the magnitude of the required resources. Even smaller projects like NHRE and METROMEX require a concentration of resources unlikely to be made available other than through the Federal agencies.

The Federal research effort in weather modification has been subject to persistent criticism by various review groups during the past few years. The most consistent criticisms include the lack of a National policy, fragmented programs, and subcritical funding levels.[6,7,8/] In their recent review of the administration of Federal weather modification research, for example, the General Accounting Office indicated concern for the fragmented nature of past research activities and cited the lack of

6/ A Report to the President and The Congress, National Advisory Committee on Oceans and Atmosphere, First Annual Report, June 30, 1972.

7/ Weather and Climate Modification, Problems and Progress, Committee on Atmospheric Sciences, National Academy of Sciences, Washington, D.C., 1973.

8/ Need for a National Weather Modification Research Program, Report to the Congress B-133202, August 23, 1974, Comptroller General of the U.S. General Accounting Office, Washington, D.C.

central management of the overall research effort. The Subcommittee, taking these criticisms into consideration during its deliberations, came to the following conclusions with regard to the present state of affairs:

- To the extent that a National policy on research in weather modification can be identified[9/] it reflects the present Federal strategy of developing techniques to achieve particular objectives such as augmenting water resources or diminishing the damage from hurricanes. This strategy does not view the development of a weather modification science and technology as a national goal whose achievement would allow many different applications as needs arise.
- This strategy, which encourages the individual agencies to conduct weather modification research in pursuit of their assigned missions, has divided the research responsibility, while budgetary limitations over the past several years have produced a situation in which many individual projects are marginally staffed, funded, and operated. This divided responsibility approach lends itself to the criticism of "fragmentation" by some.[6,7,8/]
- The level of scientific and technological complexity of even modest weather modification experimentation requires a higher level of funding than has usually been available to accomplish individual project goals. This finding is consistent with recent conclusions

9/ Letter from Norman E. Ross, Jr., Assistant Director, Domestic Council, to Congressman Gilbert Gude, Congressional Record - House, June 17, 1975, p. H5629.

reached by the National Academy of Sciences and the National Advisory Committee on Oceans and Atmosphere.[6, 7/]

- While progress has been generally slow and uneven, some advancement has been achieved over the past two decades in several types of weather modification research under existing policies. This finding is in agreement with conclusions reached in the reports cited above.
- Fundamental knowledge concerning physics and dynamics of cloud processes is inadequate. This finding is consistent with the general view expressed by the recent American Meteorological Society cloud physics review.[10/] The lack of the necessary scientific base is one of the major bottlenecks impeding development of useful, deliberate weather modification techniques. Other scientific and technical aspects of weather modification also need improvement; for example, observation systems, techniques of evaluation, and delivery systems.

In light of the economic losses and potential benefits discussed in the opening section of this report, the Subcommittee concludes that weather modification represents an important potential tool for exerting influence over destructive and disruptive weather events. Successful weather modification techniques to favorably influence weather elements would have a high benefit/cost ratio. As the population continues to grow and becomes increasingly concentrated in regions of severe weather and as the demand for water for agriculture, industry, and domestic use grows, the

10/ "Cloud Physics", Roscoe R. Braham, Jr., and Patrick Squires, Bulletin of the American Meteorological Society, Vol. 55, No. 6, June 1974, pp 543-586.

possibilities for effective weather modification are likely to appear even more attractive as a means for augmenting the economy and preventing disasters. There remains, however, the serious question of possible disbenefits or ancillary consequences. Only through additional research can the ultimate potential of weather modification be estimated accurately. The Subcommittee recommends, therefore, that

- *The Federal Government recognize weather modification as having significant potential for ameliorating important weather-related problems and foster a broad-based effort of research and experimentation in weather modification designed to realize this potential during the next decade.*
- *The Federal Government examine its institutional structure for planning and management of the national weather modification effort to carry out its responsibilities for research and experimentation. The Subcommittee identified two practical institutional options but could not achieve consensus on either.*[11/] *A decision should be made between the following options:*

  Option (1) Continue coordination and planning of the national weather modification effort through the Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology, with individual agencies pursuing their mission responsibilities.

11/ Appendix A presents views submitted by those agencies wishing to comment on these options.

Option (2) Establish a lead agency to foster the broad advancement of the science and technology of weather modification as recommended by the National Advisory Committee on Oceans and Atmosphere, the National Academy of Sciences, and other groups to coordinate and plan the national effort with the assistance and participation of other agencies.

- *Weather modification research in general be funded at an increased level to ensure that present marginal efforts can be transformed into significantly more productive activities.* A number of scientific bodies have looked at the level of funding needed for a comprehensive weather modification program. In 1966, the National Academy of Sciences suggested that some $30 million in Federal support would be required by fiscal year 1970. The Federal Council for Science and Technology (Newell Report), on the basis of a much more thorough study of agency requirements, recommended a figure of about $90 million for fiscal year 1970. The National Academy of Sciences, in its 1973 report, estimated that no less than $50 million will be required annually to implement their recommended national program. We as a Subcommittee believe there is now a need for a new plan or assessment as to what is required, and that such a plan should be prepared by the Federal group or agency with central responsibility as determined by the previous recommendation.

- *The Federal Government develop and support a more vigorous program of fundamental research and experimentation in the physics and dynamics of cloud processes to advance weather modification technology and its application.*
- *Greater emphasis in research be placed on the assessment of the socioeconomic and environmental impacts of weather modification.* There are many cases where field experimentation has encountered serious difficulty because of public (social) impact or the concerns expressed by foreign governments. More important is the need to provide input for rational decisions concerning the possible application of the developed technology.
- *Greater emphasis be placed on the development of improved methodologies to evaluate the effects of weather modification.* This recommendation has been made because this is a major obstacle to efficient experimentation and to effective monitoring of weather modification operations. Current evaluation methods are not adequate to distinguish natural from man-made changes.

B. Operations

Federal weather modification programs generally have been limited thus far to research and development activities. However, depending upon the definition selected, there have been some domestic activities that could be termed operational.

Because of severe drought in 1971, emergency cloud seeding efforts for drought alleviation in Arizona, Texas, and Oklahoma were undertaken by the Bureau of Reclamation at the request of the governors of those states and at the direction of the Office of Emergency Preparedness. The National

Oceanic and Atmospheric Administration also expanded its ongoing research project in seeding tropical cumulus clouds in Florida in 1971 in response to an appeal by the Governor of Florida for drought alleviation assistance. In addition, the Department of Defense has undertaken operational weather modification to disperse fog at several of its military installations.

The Bonneville Power Administration of the Department of the Interior proposed to utilize cloud seeding operationally to help relieve a critical power shortage in the Pacific Northwest in the fall of 1973 by augmenting precipitation in the drainage basin above Hungry Horse Dam in Montana. The project was never implemented because a change in weather conditions made it unnecessary. However, there are plans to consider implementing the project should conditions again warrant such action.

There has also been limited Federal application of existing lightning suppression and precipitation enhancement seeding techniques in an attempt to decrease initiation of lightning-caused forest fires or suppress on-going fires in Alaska. A seeding capability was tested and deployed, though not actually used, at Cape Canaveral in connection with Apollo-Soyuz and Viking launches during the summer of 1975.

Results from most Federal research projects have not yet reached a generally acceptable level of statistical significance; research in some areas of weather modification is not presently considered to have reached the experimental state (tornadoes, blizzards, and flood control), nor have anticipated economic benefits or environmental effects been fully determined. Nevertheless, many nonfederal groups, after weighing the uncertainties, have proceeded to implement operational programs.

In a report on weather modification activities in the United States covering calendar year 1974, a listing of 74 reports submitted to NOAA shows that there were 65 nonfederally sponsored operational projects conducted in 22 different states, most in the West.[12/] The data also show that there were three principal purposes for the activities: precipitation increase, fog dispersal, and hail decrease. Sponsors of these operational activities included states, cities, counties, municipal districts, airport authorities, community associations, power companies, airlines, and others.

Although few operational weather modification techniques have been thoroughly proven, the Subcommittee finds that several techniques are sufficiently close to a stage of proven effectiveness that they should be considered as management options in some situations. For example, given the proper conditions, precipitation can be increased from cold orographic winter clouds and from individual cumulus clouds, and supercooled fogs and low stratus can be dissipated over limited areas. Although success has been claimed in other operations such as hail modification, these operational weather modification activities have not been subjected to the kind of scrutiny required for substantiating such claims.

In view of this finding and because of expected increased public pressure for Government action to cope with critical water shortages, periodic droughts, destructive storms, and other weather phenomena, the Subcommittee believes that relative roles of the Federal Government and the nonfederal sector in the operational application of weather modification should be clarified. Accordingly, the Subcommittee recommends that:

12/ Weather Modification Activity Reports - Calendar Year 1974, Environmental Modification Office, National Oceanic and Atmospheric Administration, Rockville, Maryland, March 1975.

- *When and if weather modification techniques are determined feasible and desirable for a given situation, the Federal Government reserve for itself the responsibility in the following areas:*
  - *Precipitation modification related to water resources benefiting several states and to projects under Federal jurisdiction.*
  - *Weather modification to improve conditions over airports, roads, ports, National Forests, and other lands under Federal jurisdiction.*
  - *Mitigation of large-scale (more than one State) developing drought, with the concurrence and cooperation of the States involved, where it is determined that the effects may be widespread or threaten the Nation's welfare.*
  - *Mitigation of hurricanes and other extensive storm systems which affect more than one state and represent a major threat to life and property.* Tornadoes pose a special problem because of their local and short-term, but extremely severe, effects. Because there is no known technique for dealing with the tornado problem, the Subcommittee feels that it is inappropriate to make a recommendation with regard to relative roles at the present time.
- *The States and private sector be encouraged to consider operational weather modification as a management option addressed to problems other than those specified above as being a Federal responsibility.* A number of states have already adopted weather modification legislation and some have initiated extensive

operational programs.

- *Private sector capabilities be used in the conduct of Federal weather modification operations where both feasible and desirable.*

C. Regulation

Currently, Federal legislation does not provide for regulation or control of weather modification activities. The only Federal legislation and rules associated with weather modification deal with the reporting of nonfederal projects to the Department of Commerce under Public Law 92-205. Federal projects are also reported to the Department of Commerce by inter-agency agreement.

The rules that implement the reporting law provide a viable mechanism for gathering information in the United States on project details as well as related environmental impact and safety considerations. The reporting program also allows State officials and project personnel to be alerted if an activity poses a possible hazard to the public, property or the environment, or interference with Federal research. Since the program was initiated in 1972, no alert notices have been issued. Although more restrictive legislation has been proposed, the reporting law remains the only applicable Federal regulation on weather modification.

On the state level, approximately thirty states have enacted legislation relating to weather modification. These statutes range from simple acknowledgement of weather modification to strict requirements for such items as licenses, permits, financial responsibility, public notices, tax levies, and penalties. The most recent state laws are more sophisticated in their coverage than earlier legislation. A few states are now considering new legislation or amendments to present laws. Thus, in the United

States, weather modification is controlled by the States, with a varying degree of regulation.

Three years ago, a detailed study[13/] summarized and analyzed the various needs for Federal regulation in the field of weather modification. That paper concluded that all nonfederal weather modification projects should be prohibited unless a Federal permit was first obtained. The grounds for review of proposed projects would have been limited to interference with federally sponsored projects and protection of the public and of the national environment. The issuance of a Federal permit would signify merely that the Federal Government was satisfied on those two grounds.

The recommendations as contained in that paper were based upon the following findings made in 1972 that:

A. "There is a substantial and growing amount of weather modification activity in the United States. --- Extensive operational programs are being carried out by the private sector.

B. "The present state of the art in weather modification varies with the phenomena involved, but is advancing rapidly.

C. "There is a real and growing concern over interference between and among weather modification programs, particularly between private operations and extensive research programs supported by Federal funds.

D. "Projects may have significant adverse environmental effects, ranging from immediate hazards to life and property to long-term alterations in land use patterns and threats to ecological systems.

13/ Federal Regulation of Weather Modification, December 22, 1972, staff paper, the Council on Environmental Quality, Washington, D.C.

E. "The purpose, scope and adequacy of (State laws) have varied widely."

Examination of current information and the Subcommittee's hearing testimony shows that the findings of three years ago require qualification. It now appears that:

A. A rapid growth of weather modification activity has not continued in the Federal and nonfederal sectors. Federal funding of weather modification research has decreased about 25 percent; funding for the private sector is not known, but no dramatic increase has been indicated. The number of projects, operators and States involved has shown no sustained growth. The conclusion is that weather modification activities in both the Federal and nonfederal sectors are substantial and steady. Generally, there are fewer projects in fewer states with fewer operators, but the total target area is increasing.

B. The state of the art of weather modification has not advanced as speedily as anticipated.

C. Interference between and among weather modification activities has not been a problem in the past three years.

D. To the extent that environmental effects have been investigated, no short-term adverse effects have been substantiated. The question of long-term impacts remains open.

E. State laws have tended to become more comprehensive. Major issues or problems due to State laws governing weather modification have not developed.

In view of the above the Subcommittee finds that additional Federal regulatory legislation is not needed at this time and reporting procedures have fulfilled an important need. However, given the still significant amount of activity in the field as well as the potential for increased use of the technology, prudence dictates a continuing examination of the need for Federal laws and regulations and international treaties and agreements to govern weather modification activities. This conclusion is based on the overriding considerations that weather phenomena cross state and national boundaries and improperly conducted weather modification may adversely affect public welfare.

In addition, weather modification activities may have effects outside U.S. territory and thus have an important impact on our foreign relations. An earlier concern by Canada on a proposed cloud seeding project in Washington State that could affect Canadian territory is a case in point. As a result of this and related concerns, the U.S. and Canada signed an agreement on March 16, 1975, to exchange information on weather modification activities conducted within 200 miles of the international boundary. Such considerations demand a continued Federal role in gathering information on weather modification activities in close coordination and consultation with the Department of State.

In light of the Subcommittee's evaluation concerning the need for regulation of weather modification, it is recommended that:

- *A formal procedure be established for the periodic reassessment of regulatory needs, based on an ongoing review of operational weather modification activities.*

- *The design and implementation of future U.S. domestic and foreign weather modification activities include prior assessment of the potential international implications.*

A LEAD AGENCY FOR THE NATIONAL WEATHER MODIFICATION RESEARCH PROGRAM

The Departments of Commerce, State and Transportation and the National Aeronautics and Space Administration have examined the institutional options presented on pages 19 and 20 of the Subcommittee on Climate Change report, "The Federal Role in Weather Modification," and subscribe to option 2. This option calls for the establishment of a lead agency to foster the broad advancement of science and technology of weather modification. We strongly support the position that establishing a lead planning and coordinating agency for weather modification research and development would provide the basis for a more productive and effective national program, and we recommend that the National Oceanic and Atmospheric Administration (NOAA) be assigned this lead agency responsibility.

Various review bodies are identified in the Subcommittee report as advocating the lead agency approach. These groups have argued that a lead agency is needed to achieve the following objectives:

- To provide a central focus for the overall weather modification research and development effort.
- To overcome fragmentation and duplication in past weather modification research activities.
- To develop a national program with goals, objectives, priorities, and milestones.
- To develop a plan to allocate resources to the national program elements.

- To effectively coordinate activities of Federal departments and agencies providing support to or conducting weather modification research.
- To provide the scientific and management competence, the dedication, and the resources necessary to make the national goals in weather modification an integral part of its basic mission.

For the above reasons and because of our conviction that technologies for different modes of weather modification that one would wish to develop for different application all flow from a common font of science and experimentation, we subscribe to the view that the science could best be served by assignment of lead responsibility to an appropriate agency.

We feel that the charter for this lead responsibility should include the following:

- The lead agency would assume the leadership for planning the federal weather modification program, in concert with those other concerned agencies, universities, and the private sector.
- The lead agency would present, within the Executive Branch, a consolidated national weather modification research plan and be available to represent the national plan before the Congress.
- The lead agency would, within the framework of the joint planning effort, encourage and assist in justifying programmatic activities in other agencies that might contribute significantly to the national weather modification objectives, especially when those programs can be implemented as supplements to the agencies' on-going mission-related activities.

- The lead agency would take on the responsibility for presenting the budgetary requirements to carry out the national plan to the Office of Management and Budget and, with due consideration of overall priorities of the agency, would seek to provide within its own budget for activities essential to the national plan and not incorporated in the budgets of the other agencies.

It is expected that other departments and agencies, because of their continuing responsibility for the application of weather modification, would provide for the necessary financial support within their individual agency budgets.

The recommendation that NOAA be designated the lead agency for weather modification research stems from its broad weather responsibilities as the principal national civil weather agency. These broad weather responsibilities give NOAA a broad range of managerial, technical, and facility capabilities suited to the role of a lead agency. It should be emphasized that, within the framework of the designation of NOAA as lead agency, it is expected that the National Science Foundation would continue to have the primary responsibility for supporting the basic science and the fundamental research at the universities and at the National Center for Atmospheric Research. Other Departments, such as Interior and Agriculture, would continue to exercise responsibilities for application of weather modification in support of their missions. The National Aeronautics and Space Administration would continue to have primary responsibility for supporting research and development in the application of space technology to problems in weather modification. The Department

of State would exercise the responsibility for assessing the impacts of weather modification activities on U.S. international relations and formulate foreign policy positions relevant to such activities.